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TITLE: Buoyancy-Driven Electric Power Generator

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## **BUOYANCY-DRIVEN ELECTRIC POWER GENERATOR**

### **BACKGROUND OF THE INVENTION**

5           Generation of electric power is a necessary component for the  
operation of modern society. Alternatives to conventional electric power  
generation sources fueled by coal or nuclear materials continue to be  
explored. One of the most inexpensive and cleanest methods for generating  
large amounts of electric power is hydroelectric power generation. The use of  
10       hydroelectric power generation, however, is limited because it requires the  
availability of vast quantities of water and the feasibility of constructing a large  
dam to store the large amount of water. Moreover, the geological sites where  
the requisite conditions for hydroelectric power generation can be satisfied are  
few and far between. These limitations often require reliance on other means  
15       of power generation such as nuclear and fossil fuel power plants, which are  
expensive and environmentally unattractive.

Other sources of energy, such as wind and solar power, are  
environmentally clean and relatively inexpensive. However, a large-scale  
utilization of these sources for electric power generation is not currently in  
practice because of several limitations that are inherent in these methods.  
For example, wind power and solar energy both require a disproportionately  
large surface area for a large-scale operation. Further, these methods are  
unreliable because of their dependence on the weather conditions. Thus, it is  
difficult to obtain continuous generation of a large amount of electric power  
20       through wind power or solar energy.

25           Because of the inherent limitations of most power generation methods,  
it would be desirable to develop an alternative power generation method that  
could provide power with the benefits of hydroelectric generation, but with  
reduced geographical restrictions.

## DEFINITIONS

Buoyancy force is a form of gravitational force. For ease of explanation, however, "gravity" or "gravitational" will be used for scenarios in which the capsule is denser than the surrounding environment. "Buoyant" or "buoyancy" will refer to scenarios in which the capsule is less dense than the surrounding environment, and thus rises upwardly. "EMF," otherwise known as electromotive force, is any voltage induced by moving a conductor across a magnetic field.

## BRIEF SUMMARY OF THE INVENTION

The present invention pertains to a new method and system of electric power generation, which requires neither large amounts of water nor a large dam construction. The present invention pertains to a Buoyancy-Driven System (BDS), which uses the motion of magnet capsules through coil modules to generate electric power. Like the typical hydroelectric power system, the BDS uses gravitational energy. The BDS, however, also makes use of buoyancy force in accordance with Archimedes' Principle.

In the conventional hydroelectric power system, fast-flowing water held back by a dam turns the turbine in an electric generator. The water rushing out of the dam is under high pressure caused by the weight of the water in the reservoir. The energy utilized to turn the generator is gravitational in origin, i.e., a conversion of gravitational energy to electrical energy. The electric power is generated when the magnetic field of the rotating magnetic rotor induces an EMF in the static coil that surrounds the magnetic rotor or, conversely, that rotation of a coil in the magnetic field of a fixed magnet causes an induced EMF in the rotating coil.

The BDS uses gravitational energy, in the form of gravity and buoyancy. Instead of either the water falling in the gravitational field or the fast-flowing water under high pressure from the weight of the water in the reservoir, the BDS uses buoyancy force. In the BDS, a plurality of buoyant

magnet capsules are placed in a portion of a fluid-filled area. Because the magnet capsules are buoyant in surrounding fluid, buoyancy force drives the capsules upward in the fluid. As the capsules move upward, the magnetic fields of these magnet capsules induce an EMF in a plurality of coil modules that are situated on the exterior surface of portions of the loop. The size and configuration of the coil modules on the external surface of the loop are dictated by the strength and distribution of the magnetic fields generated by the magnet capsules. The coil modules may be placed on the exterior surface of the liquid-filled portion and/or the empty portion of the loop.

The BDS utilizes a containment loop which contains a buoyancy section, a slide-and-fall section, and a capsule injector. The containment loop ensures that the magnet capsules move in a predetermined path. The buoyancy section is filled with fluid. Typically, this fluid is water. However, other liquids, such as engine oil, may be utilized. Indeed, in certain embodiments, oil may be a preferable liquid due to reduced friction. The magnet capsules rise from a lower portion to an upper portion of the buoyancy section. The momentum of the magnet capsules carries them into the slide-and-fall section. The slide-and-fall section allows gravity to return the capsule from an upper elevation to a lower elevation.

In between the bottom of the buoyancy section and gravitational section, there is a capsule injector. The capsule injector receives a magnet capsule from the low-pressure gravitational section and introduces it into the high-pressure buoyancy section. In a preferred embodiment, the capsule injector operates much like a lock in a canal. There are two gates, an entrance gate on the low pressure side and an exit gate on the high pressure side. When the entrance gate is opened, the weight of the stacked magnet capsules in the capsule waiting portion of the slide-and-fall section will push the next waiting capsule into the capsule injector. Upon entering the capsule injector, a volume of liquid equal to the volume of the capsule is displaced. The displaced liquid may exit the loop via a drainage pipe that is situated off the slide-and-fall section. The displaced liquid may be pumped to the buoyancy section in order to recycle the liquid in the BDS. Once the magnet

capsule is in the capsule injector, the entrance gate is closed. Next, the exit gate is opened. The magnet capsule is now subjected to the high pressure buoyancy section. At this point, the magnet capsule will rise from the bottom to the top of the buoyancy section.

5           The motion of a capsule through the BDS loop generates electric power. A changing magnetic flux passing through a wire loop will induce a current in the loop. Thus, the movement of a magnet capsule through a coil module will induce a current, and generate electric power. The BDS loop operates as a continuous cycle in which the magnet capsules are driven  
10           upward via buoyancy force and taken back downward using gravity. Because buoyancy and gravitational forces drive the magnet capsules through the BDS loop, EMF may be generated in either or both of the buoyancy or gravity portions of the BDS loop by placing coil modules surrounding those portions of the BDS loop.

15           The BDS offers a clean method of generating power. The BDS uses gravity, which includes buoyancy force, to drive magnet capsules through the BDS loop. The only energy consumed in the BDS is through the operation of the capsule injector and, if used, a refill pump for recycling the liquid utilized. Thus, with the appropriate design characteristics, the BDS can be a self-sustaining system.  
20

## BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

Fig. 1 is a cross-sectional view of one preferred embodiment of the BDS loop.

25           Fig. 2 is a graphical representation of the forces that act upon a buoyant magnet capsule placed in a liquid-filled portion of the loop.

Figs. 3(a) – (d) depict the injection of magnet capsules through an embodiment of a capsule injector for use with the present invention.

30           Fig. 4 depicts an embodiment of a capsule injector for use with the present invention.

Fig. 5 depicts an embodiment of a magnet capsule for use with the present invention.

Fig. 6(a) and (b) depict embodiments of coil modules for use with the present invention.

Fig. 7 depicts another embodiment of a capsule injector for use with the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

The Buoyancy Driven System (BDS) generates electric power by passing a plurality of magnet capsules through any plurality of coil modules. The number of capsules and coil modules are a matter of design preference, and could conceivably include only one of each. The BDS uses the laws of induction to generate EMF. According to Faraday's Law, EMF is related to the rate of change of magnetic flux. Thus,

$$e = -N \frac{d\phi}{dt}$$

where  $e$  is the induced EMF,  $N$  is the number of turns in the coil,  $\Phi$  is the magnetic flux passing through the coil, and  $\frac{d\phi}{dt}$  is the rate of change of the magnetic flux.

Both conventional hydroelectric power generation and the BDS use the well-known principles of induction to generate electric power. The conventional hydroelectric power generator uses the force of rushing water to rotate a magnet around a stator at an angular frequency. The angular movement of the magnet will generate a changing magnetic flux that, in turn, induces an EMF. In the BDS, on the other hand, buoyancy and gravitational forces act linearly on the magnet capsules. As the magnet capsules pass through the BDS loop and surrounding coil modules, EMF is generated.

As shown in Figure 1, the preferred embodiment of the BDS loop **100**, also known as the containment loop **100**, is preferably a closed loop of pipe. However, any other area in which a portion may be filled with liquid may be utilized. Additionally, a perforated portion of pipe submerged in a body of liquid may be used. In a preferred embodiment, the BDS loop **100** is made of a non-magnetic material, such as aluminum, PVC, or rubber. A non-magnetic

material is preferable because it will have negligible effects on the magnetic fields emanating from the magnet capsules **120**. In an alternative embodiment, one may determine that construction with magnetic materials is acceptable or beneficial. Additionally, it is preferable to utilize a large elevation range to increase the amount of buoyant and gravitational force acting during a cycle around the BDS loop **100**. Construction on a hilltop, in the ocean, drilling into the ground, or in a tall building may all provide a large elevation range. While a large elevation range will increase the efficiency of the BDS, it is not necessary to practice the present invention.

In the preferred embodiments of the present invention, electric power is generated by the motion of magnet capsules **120** through coil modules **150**. In a preferred embodiment, the coil modules **150** surround portions of the BDS loop **100**. The coil modules **150** may be placed at any location on the BDS loop, internally or externally. In the presently preferred embodiments, coil modules **150** are located on the buoyancy section **130** and/or the gravitational section **140**.

At the bottom of the BDS loop **100**, capsule injector **110** inserts magnet capsules **120** into the buoyancy section **130** of the BDS loop **100**. The buoyancy section **130** is filled with a fluid. When the magnet capsule **120** is inserted into the bottom of the buoyancy section **130**, the lower density of the magnet capsule **120** will cause it to float to the top due to Archimedes' Principle. The velocity of the magnet capsule **120** is determined by the various forces acting on the capsule **120**.

Figure 2 shows a magnet capsule **120** placed in a portion **200** of the buoyancy section **130**, which is filled with fluid **210**. The capsule **120** is pulled down by a gravitational force,  $F_g$ , **220** and raised up by the buoyancy force,  $F_b$ , **230**. A drag force,  $F_d$ , **240** also acts on the capsule **120** to slow it down as it moves through the buoyancy section **130**. The capsule reaches a steady-state velocity when the opposing forces are exactly balanced. In this instance,

$$(F_b - F_g)\cos\theta = F_d$$

where  $\theta$  is the angle of orientation **250** of the pipeline with respect to the vertical axis along which buoyancy force **230** and gravitational force **220** lie.

According to Archimedes' Principle, the buoyancy force **230** acting on the capsule **120** is equal to the weight of the water that it displaces. This is represented by the formula:

$$F_b = \rho V g$$

where  $\rho$  is the density of the liquid,  $V$  is the capsule volume, and  $g$  is gravitational acceleration.

The gravitational force **220** is represented by the equation:

$$F_g = mg$$

where  $m$  is the capsule mass and  $g$  is gravitational acceleration.

The drag force **240** is comprised of two components: a fluid drag and an inducement drag. The fluid drag is represented by the equation:

$$F_d = \eta v$$

where  $\eta$  is a proportionality constant that depends on parameters characterizing the hydrodynamics of the capsule's motion such as the viscosity of the liquid and size and shape of the capsule, and  $v$  is the velocity **260** of the capsule **120**.

By solving the equations, the steady state velocity **260** is determined from the fluid drag to be

$$v = \frac{1}{\eta} (\rho V - m) g \cos \theta$$

for  $(\rho V - m) > 0$ .

In addition to velocity reduction caused by the fluid drag, intermittent velocity reductions will occur due to inducement drag. The inducement drag is created when the magnet capsule **120** is in proximity with the coil module **150**. As the magnet capsule **120** passes through the coil module, the coil is magnetized in a way to oppose the magnetic field of the capsule. As a result, an EMF is induced in the coil with a polarity that opposes the field of the inducing magnet capsule. The inducement drag is proportional to the induced EMF, which is proportional to the time rate of change of the magnetic flux that

passes through a coil. The time rate of change of magnetic flux is proportional to the peak strength of the magnetic field and the speed of the capsule through the coil. As the magnet capsule **120** approaches the coil module **150**, the inducement drag will slow down the magnet capsule **120**.  
5 Nonetheless, the buoyancy force **230**, if the capsule **120** is in the buoyancy section **130**; or the gravitational force **220**, if the capsule **120** is in the gravitational section **140**, will push the capsule **120** forward. Moreover, when the magnet capsule **120** leaves a coil module **150**, the capsule will return to the steady state velocity.

10 If the steady state velocity is sufficient, the momentum of the magnet capsule will carry it into the buoyancy release portion **142**, which meets the top of the buoyancy section **130**. The buoyancy release portion **142** marks the beginning of the gravitational section **140** of the BDS loop **100**.

15 After the momentum of the magnet capsule **120** carries it through the buoyancy release portion **142**, the magnet capsule is pulled downward by gravity in the slide and fall portion **144** of the gravitational section **140** of the BDS loop **100**. In a preferred embodiment, the buoyancy release portion **142** and slide and fall portion **144** of the gravitational section **140** are not filled with liquid. At the bottom of the slide-and-fall section **146**, there may be a low pressure collection of liquid. The presence or absence of fluid in the  
20 gravitational section **140** is immaterial to the present invention so long as the capsule **120** is denser than its surroundings and will fall downward due to gravity. In a preferred embodiment, the slide-and-fall section **144** may be fully or partially curled into a helical shape. The use of a helical shape will  
25 increase the path length of the slide-and-fall section **144**, thereby accommodating a larger number of coil modules **150** with which the capsules **120** may interact.

30 At the bottom of the gravitational section **140**, the capsule holding section **146** holds magnet capsules **120** waiting to be placed into the capsule injector **110**. Here, the collective weight of the capsules presses down on the capsules in proximity to the capsule injector **110** thereby pushing the next capsule **320** into the capsule injector **110**.

The present invention utilizes the BDS loop to generate electric power through the use of the buoyancy and/or gravitational forces. A plurality of magnet capsules **120** are less dense than the surrounding water, thus are forced upward through the buoyancy section **130** of the BDS loop **100**.

5 Surrounding the buoyancy section **130** are coil modules **150**. The coil modules **150**, situated on the exterior of the pipe, generate power from the magnetic flux that is induced by the upward movement of the magnet capsules **120**. Embodiments of the coil modules **150** are shown in Figures 6(a) and (b) and described below.

10 The present invention uses the linear motion of a magnet through a coil to generate electricity. In this manner, electricity can be generated at any point in the BDS loop **100** where a magnet capsule **120** is moving through a coil module **150**. Thus, electricity may be generated in both the buoyancy section **130** and the gravitational section **140**.

15 In Figure 3, the operation of a two-gate capsule injector **370** is depicted. The capsule injector **370** contains an in-gate **300** and an out-gate **310**, and operates much like a lock in a canal or a torpedo tube in a submarine. As shown in Figure 3(a), a first waiting capsule **320** resides in a low pressure body of water **350**. As noted above, a different liquid may be used instead of water. Behind the first waiting capsule **320** is a second waiting capsule **330**. When the in-gate **300** is opened, the weight of the other waiting capsules in the capsule holding area **146** of the BDS loop **100**, pushes the first waiting capsule **320** into the "lock" portion of the capsule injector. When the in-gate is closed, as shown in Figure 3(b), the second waiting capsule **330** takes the place of the first waiting capsule **320**, which is now located in between the in-gate **300** and out-gate **310**, and a third waiting capsule **340** has taken the place of the second waiting capsule **330**. Next, as shown in Figure 3(c), the out-gate **310** is opened and the capsule **320** is exposed to the high pressure body of water **360**, or other liquid. Figure 3(d) returns to the beginning of the injection cycle.

25  
30 As shown in Figure 4, a preferred embodiment of the two gate capsule injector **370** is aligned such that the out-gate **310** is higher than the in-gate

**300.** With this alignment, the buoyancy force **230** acts immediately on the first waiting capsule **320**, thereby pulling it into the buoyancy section **130** of the BDS loop **100**.

The gates of the capsule injector **370** may be opened and closed in a variety of ways, including hydraulics, electromagnetics, or mechanical means. The gates may also be programmed to run automatically with a cycle period properly adjusted to a desired spacing of the capsules ascending in the buoyancy section **130**. The energy produced by the BDS may also be used as a source for the operation of the capsule injector **110**.

Because the water, or other liquid, from the buoyancy section **130** is displaced to the capsule in waiting portion **146** of the BDS loop **100**, a drain **160**, as shown in Figure 1, may be utilized to remove liquid from the gravitational section **140** of the BDS loop **100**. A refill pipe **170** may also be used to refill the water, or other liquid, into the top of the buoyancy section **130**. Further, in another embodiment, the buoyancy section **130** may be perforated to allow a surrounding body of liquid to refill the liquid displaced during capsule injection.

Figure 5 depicts a magnet capsule **120** that may be used with the present invention. The capsule **120** includes a magnet **400** that is placed inside a casing **410**. It is preferable to utilize a casing that is light and sturdy. For example, aluminum or fiberglass reinforced plastic may be satisfactory materials for the casing. The magnet **400** in a preferred embodiment is a permanent magnet. This magnet may be a simple bar magnet as shown in Figure 5, a ring-shaped magnet, an arrangement of a plurality of magnets, or other type of magnet. It is preferable to utilize a permanent magnet, but electromagnets driven by batteries may also be used. The type of magnet is a matter of design choice and is not essential to the present invention. The space inside the capsule not occupied by the magnet may be left empty or filled with a light material, such as Styrofoam. The capsule **120** is designed to optimize the buoyancy force when it is in the buoyancy section **130**, while allowing for sufficient gravitational force when it is in the gravitational section **140**.

Figures 6(a) and (b) depict coil module embodiments that may be used in accordance the present invention. The coil module **150** is a coil of wire wound and mounted on the exterior surface of the BDS loop **100**. The coil module **150** may be thought of as the linear version of the circular stator coil of the conventional shaft-motion generator of comparable dimensions. Likewise, the magnet capsule **120** may be thought of as the linear counterpart of the magnetic rotor of the conventional shaft-motion generator. Thus, one engagement of a magnet capsule **120** with one coil module **150** is equivalent to one turn of revolution of the conventional shaft-motion generator of comparable dimension. In a preferred embodiment, the coil module **150** is mounted along the buoyancy section **130** and slide and fall portion **144**. The design of the coil module **150** is dependent on the type of magnet capsule **120** utilized and the type of accompanying electrical system for collecting and processing the electric power. As with the choice of magnet capsule or capsule injector, any one particular coil module is not essential to practice the present invention.

Figure 6(a) shows a single coil module **500**. In the single coil module **500**, a ferromagnetic skin **510** is located around the exterior of the coil module **500**. The single coil module **500** induces an EMF through the magnetic flux internal to the capsule magnet. Figure 6(b) shows a compound wound coil module **530**. The compound wound coil module **530** utilizes a ferromagnetic core **540** and induces an EMF through the external magnetic flux.

Different embodiments may also be used for the capsule injector **110**. Figure 4 depicted a two-gate capsule injector **370**. As shown in Figure 7, another embodiment may utilize ball shaped stoppers. In the ball stopper embodiment **700**, there is a first ball valve **710** and a second ball valve **720**. The ball valves **710** and **720** have a density larger that the surrounding fluid, while the capsules **120** have a density that is smaller than the surrounding fluid. The net weight of a ball valve, which is equal to the gross weight minus the buoyancy force acting upward on the ball valve, is smaller than the net buoyancy force acting on the capsule, which is equal to the gross buoyancy force acting on the capsule minus the weight of the capsule.

The ball stopper capsule injector **700** includes a first chamber **730**, second chamber **740**, and an electric valve **750**. When the electric valve **750** is closed, the first chamber **730** is filled with high pressure fluid **760** due to the weight of the fluid in the buoyancy section **130**, while the second chamber **740** is filled with lower pressure fluid **770**. The high pressure acting on the first ball valve **710** keeps it securely in place blocking the entrance of the first chamber **730**, thus preventing the high pressure fluid **760** from entering the second chamber **740** and the first waiting capsule **320** from entering the first chamber **730**. With the electric valve **750** closed, the second ball valve **720** is lifted and pushed aside by the first waiting capsule **320** due to the low pressure of the fluid **770** in the second chamber **750** and the capsule holding section **146**.

When the electric valve **750** is opened by the activation of a solenoid **780**, the pressure in the two chambers **730** and **740** equalizes so that the fluid **770** in the second chamber **740** is now at the same high pressure as the fluid **760** in the first chamber **730**. Because the net weight of a ball valve is sufficiently smaller than the net buoyancy force of a capsule, the first waiting capsule **320** may now push the first ball valve **710** aside and enter the first chamber **730**. The buoyancy of the first waiting capsule **320** then causes the first waiting capsule **320** to be injected into buoyancy section **130**.

The second waiting capsule **330**, which is only partially in the second chamber **740** is pushed down into the capsule holding section **146** when the electric valve **750** is opened. This occurs because the pressure on the front of the second waiting capsule **330** is higher than the pressure on the rear of the second waiting capsule **330**. As the second waiting capsule **330** is pushed down into the capsule holding section **146**, the second ball valve **720** rolls down to securely block the entrance to the second chamber **740**. In this instance, the pressure difference between the second chamber **740** and the capsule holding section **146** is sufficiently large enough to push all of the capsules in the capsule holding section **146** collectively.

When the electric valve **750** is closed by deactivating the solenoid **780**, the fluid in the second chamber **770** returns to the original low pressure. The

pressure difference between the two chambers **730** and **740** keeps the first ball valve **710** securely in place, blocking the entrance of the first chamber **730**. Because the second chamber **740** and the capsule holding section **146** are now at the same low pressure, the second waiting capsule **330** is able to push aside the second ball valve **720** and a third waiting capsule **340** partially enters the second chamber **770**. At this point, the process repeats itself.

In the preferred embodiment, it is desirable to utilize a large plurality of coil modules in order to maximize the EMF generated in a given cycle. Because the size of the magnet is determined by the size and weight constraints of the capsule **120**, the magnitude of the EMF that can be attained in a single coil module **150** is limited. However, with a plurality of capsules **120** and coil modules **150**, at any given instant the total sum of electricity generated will be significant.

The BDS generates power by passing magnet capsules **120** through coil modules **150**. The BDS may also incorporate the use of one or more additional sources of energy. For example, if the BDS loop is constructed in the ocean, BDS may additionally use the motion of the waves to generate electric power. This additional energy may be used to increase the electrical power generated and/or to operate the capsule injector **110** or the pump **170**. In yet another embodiment, the BDS may additionally utilize solar energy. In a further embodiment, other sources of electrical power generation may be utilized.

The operation of the BDS may be effected by several variables including the design of the magnet capsules **120**, the coil modules **150**, the type of fluid utilized, and the capsule injector **110**. The BDS demonstrates an improvement over the prior art by implementing a novel method and system for generating electrical power in an environmentally attractive manner.